# Appendix D

## ATSDR and CDC Health Effects and Toxicological Profiles

## Molybdenum

CAS No. 7439-98-7

### General Information

Elemental molybdenum is a silver-white, hard metal widely used to add strength and hardness and retard corrosion in metal alloys. Compounds of molybdenum are also used as corrosion inhibitors, hydrogenation catalysts, lubricants, chemical reagents in hospital laboratories, and in pigments for ceramics, inks, and paints. More recently, semiconductor and battery industries have begun to use molybdenum. Molybdenum occurs in natural waters and may be present in concentrations of several hundred micrograms per liter or higher in ground and surface water near mining operations or ore deposits.

Molybdenum is a nutritionally essential trace element that enters the body primarily from dietary sources. In humans, molybdenum is a cofactor for three enzyme classes—sulfite oxidase, aldehyde dehydrogenase, and xanthine oxidase (Kisker et al., 1997). The recommended dietary allowance for adult men and women is 45 µg/day (IOM, 2001), and the average dietary daily intake of molybdenum is approximately 100 µg/day (IOM, 2001; WHO, 1996). Gastrointestinal absorption of molybdenum averages 88-93% for dietary intakes of 22-1490 µg/day. Excretion occurs predominantly via the kidneys, which exert homeostatic regulation over molybdenum balance. At a daily oral molybdenum dose of 24 µg, urinary excretion over six days was 18% of the ingested dose; at daily oral doses of 95 µg and 428 µg, urinary excretion over six days rose to 50% and 67%, respectively, of the ingested dose (Turnlund et al., 1995). In industry, dust and other fine particles produced during refining or shaping of molybdenum or molybdenum-containing alloys are inhalational pathways of exposure.

Human health effects from molybdenum at low environmental doses or at biomonitored levels from low environmental exposures are unknown. Molybdenum is generally considered to be of low human toxicity, and clinical or epidemiologic evidence of adverse effects is limited. Chronic exposure to very high levels may result in higher serum uric acid levels and a gout-like illness (Koval'skiy et al., 1961; U.S. EPA, 1993). Based on studies finding adverse reproductive effects in rats and mice, the Panel on Micronutrients of the Institute of Medicine identified a no observed adverse effect level (NOAEL) of 0.9 mg/kg/day and established a tolerable upper intake level of 0.03 mg/kg/day in humans (IOM, 2001). A long term inhalation bioassay of molybdenum trioxide in mice yielded "some evidence" of carcinogenicity (NTP, 1997). One case-control study suggested a possible link between occupational exposure to molybdenum and lung cancer (Droste et al., 1999), but available epidemiologic data are scant, and molybdenum has not been systematically evaluated for carcinogenicity by IARC.

### Biomonitoring Information

Molybdenum is an essential element for health, and urinary levels reflect intake from all sources. Levels of molybdenum in urine for the U.S. population were well characterized in NHANES since 1999-2000 (CDC, 2012); these levels were comparable to those reported for adults in smaller European population surveys (Iversen et al., 1998; Minoia et al., 2002; White and Sabbioni, 1998). Urinary molybdenum concentrations in infants may be slightly lower than those in other age groups (Sievers et al., 2001).

Finding a measurable amount of molybdenum in the urine does not mean that the level of molybdenum causes an adverse health effect. Biomonitoring studies on levels of molybdenum can provide physicians and public health officials with reference values so that they can determine whether people have been exposed to higher levels of molybdenum than are found in the general population. Biomonitoring data can also help scientists plan and conduct research on exposure and health effects.

## References

Centers for Disease Control and Prevention (CDC). *Fourth National Report on Human Exposure to Environmental Chemicals. Updated Tables*, 2012. [online] Available at URL: http://www.cdc.gov/exposurereport/. 10/26/12

# PUBLIC HEALTH STATEMENT
# RADIUM
# CAS#: 7440-14-4

**Division of Toxicology** **December 1990**

This Public Health Statement is the summary chapter from the Toxicological Profile for Radium. It is one in a series of Public Health Statements about hazardous substances and their health effects. A shorter version, the ToxFAQs™, is also available. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present. For more information, call the ATSDR Information Center at 1-888-422-8737.

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This Statement was prepared to give you information about radium and to emphasize the human health effects that may result from exposure to it. The Environmental Protection Agency (EPA) has identified 1,177 sites on its National Priorities List (NPL). Radium has been found above background levels at 18 of these sites. However, we do not know how many of the 1,177 NPL sites have been evaluated for radium. As EPA evaluates more sites, the number of sites at which radium is found above background levels may change. The information is important for you because radium may cause harmful health effects and because these sites are potential or actual sources of human exposure to radium.

When a radioactive chemical is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment as a radioactive chemical emission. This emission, which is also called a release, does not always lead to exposure. You can be exposed to a radioactive chemical when you come into contact with that chemical alone or with a substance that contains it. You may be exposed to it in the environment by breathing, eating, or drinking substances containing the radioactive chemical or from skin contact with it. Exposure can also occur by being near radioactive chemicals at concentrations that are found at hazardous waste sites or industrial accidents.

If you are exposed to a hazardous substance such as radium, several factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, sex, nutritional status, family traits, life style, and state of health.

## 1.1 WHAT IS RADIUM?

Radium is a naturally-occurring silvery white radioactive metal that can exist in several forms called isotopes. It is formed when uranium and thorium (two other natural radioactive substances) decay (break down) in the environment. Radium has been found at very low levels in soil, water, rocks, coal, plants, and food. For example, a typical amount might be one picogram of radium per gram of soil or rock. This would be about one part of radium in one trillion (1,000,000,000,000) parts of soil or rock. These levels are not expected to change with time.

Some of the radiation from radium is constantly being released into the environment. It is this release of radiation that causes concern about the safety of radium and all other radioactive substances. Each isotope of radium releases radiation at its own rate. One isotope, radium-224 for example, releases half of its radiation in about three and a half days; whereas another isotope, radium-226, releases half of its radiation in about 1,600 years.

When radium decays it divides into two parts. One part is called radiation, and the second part is called a daughter. The daughter, like radium, is not stable; and it also divides into radiation and another daughter. The dividing continues until a stable, nonradioactive daughter is formed. During the decay process, alpha, beta, and gamma radiations are released. Alpha particles can travel only a short distance and cannot travel through your skin. Beta particles can penetrate through your skin, but they cannot go all the way through your body. Gamma radiation, however, can go all the way through your body. Thus, there are several types of decay products that result from radium decay.

## 1.2 HOW MIGHT I BE EXPOSED TO RADIUM?

Because radium is present, usually at very low levels, in the surrounding environment, you are always exposed to it and to the small amounts of radiation that it releases to its surroundings. You may be exposed to higher levels of radium if you live in an area where it is released into the air from the burning of coal or other fuels, or if your drinking water is taken from a source that is high in natural radium, such as a deep well, or from a source near a radioactive waste disposal site.

Levels of radium in public drinking water are usually less than one picocurie per liter of water (about one quart), although higher levels (more than 5 picocuries per liter) have been found. A picocurie (pCi) is a very small amount of radioactivity, and it is associated with about a trillionth of a gram (a picogram) of radium. (There are approximately 28 grams in an ounce.) No information is available about the amounts of radium that are generally present in food and air. You may also be exposed to higher levels of radium if you work in a uranium mine or in a plant that processes uranium ores.

## 1.3 HOW CAN RADIUM ENTER AND LEAVE MY BODY?

Radium can enter the body when it is breathed in or swallowed. It is not known if it can be taken in through the skin. If you breathe radium into your lungs, some may remain there for months; but it will gradually enter the blood stream and be carried to all parts of the body, especially the bones.

For months after exposure, very small amounts leave the body daily through the feces and urine. If radium is swallowed in water or with food, most of it (about 80%) will promptly leave the body in the feces. The other 20% will enter the blood stream and be carried to all parts of the body, especially the bones. Some of this radium will then be excreted in the feces and urine on a daily basis.

## 1.4 HOW CAN RADIUM AFFECT MY HEALTH?

There is no clear evidence that long-term exposure to radium at the levels that are normally present in the environment (for example, 1 pCi of radium per gram of soil) is likely to result in harmful health effects. However, exposure to higher levels of radium over a long period of time may result in harmful effects including anemia, cataracts, fractured teeth, cancer (especially bone cancer), and death. Some of these effects may take years to develop and are mostly due to gamma radiation. Radium gives off gamma radiation, which can travel fairly long distances through air. Therefore, just being near radium at the high levels that may be found at some hazardous waste sites may be dangerous to your health.

### 1.5 WHAT LEVELS OF EXPOSURE HAVE RESULTED IN HARMFUL HEALTH EFFECTS?

Radium has been shown to cause adverse health effects such as anemia, cataracts, fractured teeth, cancer and death. The relationship between the amount of radium that you are exposed to and the amount of time necessary to produce these effects is not known. Although there is some uncertainty as to how much exposure to radium increases your chances of developing a harmful health effect, the greater the total amount of your exposure to radium, the more likely you are to develop one of these diseases.

### 1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO RADIUM?

There are few medical tests to determine if you have been exposed to radium. There is a urine test to determine if you have been exposed to a source of radioactivity such as radium. There is also a test to measure the amount of radon, a breakdown product of radium, when it is exhaled. These tests require special equipment and cannot be done in a doctor's office. Another test can measure the total amount of radioactivity in the body; however, this test is not used except in special cases of high exposure.

### 1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The EPA has set a drinking water limit of 5 picocuries per liter (5 pCi/L) for radium-226 and radium-228 (combined).

The EPA has set a soil concentration limit for radium-226 in uranium and thorium mill tailings of 5 picocuries per gram in the first 15 centimeters of soil and 15 picocuries per gram in deeper soil.

The federal recommendations have been updated as of July 1999.

### 1.8 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop F-32
Atlanta, GA 30333

**Information line and technical assistance:**
Phone: 888-422-8737
FAX: (770)-488-4178

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

**To order toxicological profiles, contact:**

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 800-553-6847 or 703-605-6000

**Reference**

Agency for Toxic Substances and Disease Registry (ATSDR). 1990. Toxicological profile for radium. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

# PUBLIC HEALTH STATEMENT
# Radon
CAS # 14859-67-7

**Division of Toxicology and Environmental Medicine** **September 2008**

This Public Health Statement is the summary chapter from the Toxicological Profile for Radon. It is one in a series of Public Health Statements about hazardous substances and their health effects. A shorter version, the ToxFAQs™, is also available. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present. For more information, call the ATSDR Information Center at 1-800-232-4636.

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This public health statement tells you about radon and the effects of exposure to it.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites are then placed on the National Priorities List (NPL) and are targeted for long-term federal clean-up activities. Radon has been found in at least 34 of the 1,699 current or former NPL sites. Although the total number of NPL sites evaluated for this substance is not known, the possibility exists that the number of sites at which radon is found may increase in the future as more sites are evaluated. This information is important because these sites may be sources of exposure and exposure to this substance may harm you.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact. External exposure to radiation may occur from natural or man-made sources. Naturally occurring sources of radiation are cosmic radiation from space or radioactive materials in soil or building materials. Man-made sources of radioactive materials are found in consumer products, industrial equipment, atom bomb fallout, and to a smaller extent from hospital waste and nuclear reactors.

If you are exposed to radon many factors will determine whether you will be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider any other chemicals you are exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

## 1.1 WHAT IS RADON?

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| **Radioactive gas** | Radon (Rn) is a naturally occurring colorless, odorless, tasteless radioactive gas that occurs in different forms with the same atomic number but different atomic mass, called isotopes.<br><br>As radon undergoes radioactive decay, radiation is released predominantly by high-energy alpha particle emissions, which are the source of health concerns.<br><br>Radon is measured in terms of its activity (curies or becquerels). Both the curie (Ci) and the becquerel (Bq) tell us how much a radioactive material decays every second (1 Ci = 37 billion Bq = 37 billion decays per second). |
| **Natural product of the environment** | Radon isotopes are formed naturally through the radioactive decay of uranium or thorium.<br><br>Uranium and thorium (solids) are found in rocks, soil, air, and water. Uranium and thorium decay to other elements such as radium (a solid), which in turn decays into radon gas.<br><br>Uranium and thorium have been present since the earth was formed and have very long half-lives (4.5 billion years for uranium and 14 billion years for thorium). The half-life is the time it takes for half of the atoms of a radionuclide to undergo radioactive decay and change it into a different isotope. Uranium, thorium, radium, and thus radon, will continue to exist indefinitely at about the same levels as they do now.<br><br>Radon has no commercial uses. |

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| **Exists in various forms called isotopes and decays to other radioactive isotopes** | The most common radon isotope is radon-222 ($^{222}Rn$), which is part of the uranium decay chain.<br><br>An atom of $^{222}Rn$ gives off an alpha particle (which is the size of a helium atom without electrons), transforming into an atom of polonium-218 ($^{218}Po$), which later gives off an alpha particle of its own, transforming into an atom of radioactive lead ($^{214}Pb$). This process is called radioactive decay and radon decay products are called radon progeny or radon daughters. The final step in the radioactive decay of radon progeny results in the formation of an atom of stable lead which is not radioactive.<br><br>The half-life of $^{222}Rn$ is 3.82 days. Some of the radon decay products have the following half-lives: $^{218}Po$ is 3.05 minutes; $^{214}Pb$ is 26.8 minutes; and $^{210}Pb$ is 22.3 years. |

## 1.2 WHAT HAPPENS TO RADON WHEN IT ENTERS THE ENVIRONMENT?

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| **Moves to air, groundwater, and surface water** | Radon gas in the rocks and soil can move to air, groundwater, and surface water.<br><br>Decay products of $^{222}Rn$, such as $^{218}Po$ and $^{214}Pb$, are solids that can attach to particles in the air and be transported this way in the atmosphere. They can be deposited on land or water by settling or by rain.<br><br>Radon will undergo radioactive decay in the environment. |

## 1.3 HOW MIGHT I BE EXPOSED TO RADON AND RADON PROGENY?

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| **Air** | Since radon progeny are often attached to dust, you are exposed to them primarily by breathing them in. They are present in nearly all air. Depending on the size of the particles, the radioactive particulates can deposit in your lungs and impart a radiation dose to the lung tissue.<br><br>Background levels of radon in outdoor air are generally quite low, but can vary based on location and the underlying soil geology.<br><br>In indoor locations, such as homes, schools, or office buildings, levels of radon and radon progeny are generally higher than outdoor levels and may be particularly high in some buildings, especially in newer construction that is more energy-efficient.<br><br>Cracks in the foundation or basement of your home may allow increased amounts of radon to move into your home. Also, radon is heavier than ambient air, and therefore, the concentrations of radon are generally higher in the lower levels or basement of the homes. |
| **Water** | You may be exposed to radon and radon progeny by coming into contact with radon-contaminated surface or groundwater or by drinking water from wells that contain radon.<br><br>Radon in water can become airborne; it is estimated that $1/1,000^{th}$ of the radon in water may become airborne during indoor activities that use water. |

## 1.4 HOW CAN RADON AND RADON PROGENY ENTER AND LEAVE MY BODY?

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| **When they are inhaled or swallowed** | Radon and its radioactive progeny can enter your body when you breathe them in or swallow them.<br><br>Most of the inhaled radon gas is breathed out again.<br><br>Some of the radon progeny, both unattached and, attached to particles, may remain in your lungs and undergo radioactive decay. The radiation released during this process passes into lung tissue and can cause lung damage.<br><br>Some of the radon that you swallow with drinking water passes through the walls of your stomach and intestine.<br><br>After radon enters your blood stream most of the radon quickly moves to the lungs where you breathe most of it out.<br><br>Radon that is not breathed out goes to other organs and fat tissue where it may remain and undergo decay. |

## 1.5 HOW CAN RADON AND RADON PROGENY AFFECT MY HEALTH?

Scientists use many tests to protect the public from harmful effects of toxic chemicals and to find ways for treating persons who have been harmed.

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| **Lung cancer** | Many scientists believe that long-term exposure to elevated levels of radon and radon progeny in air increases your chance of getting lung cancer.<br><br>The greater your exposure to radon, the greater your chance of developing lung cancer.<br><br>Smoking cigarettes greatly increases your chance of developing lung cancer if you are exposed to radon and radon progeny at the same levels as people who do not smoke. Because tobacco is naturally sticky, many of the radon decay products actually stick to tobacco products. Therefore, when tobacco is smoked or otherwise used, these radon products may also enter your system. Breathing in other substances that cause lung cancer may also increase your chance of developing lung cancer from exposure to radon progeny. |

## 1.6 HOW CAN RADON AND RADON PROGENY AFFECT CHILDREN?

This section discusses potential health effects in humans from exposures during the period from conception to maturity at 18 years of age.

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| **Differences between children and adults** | Smaller lungs and faster breathing rates in children may result in higher estimated radiation doses to the lungs of children relative to adults. However, limited information from children employed as miners in China do not provide evidence of increased susceptibility to the effects of exposure to radon. |

## 1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO RADON AND RADON PROGENY?

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| **Reduce indoor exposure levels** | Indoor radon levels can be reduced by methods that include the sealing of surfaces between the ground and the building and installation of ventilation systems that route air from materials under the building to outdoor air. Certified radon mitigation experts can be located by contacting your state health or environmental program. |

## 1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO RADON AND RADON PROGENY?

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| **Radon decay products in urine and in lung and bone tissues** | Radon in human tissues is not detectable by routine medical testing.<br><br>Some radon decay products can be detected in urine and in lung and bone tissue. Tests for these products are not generally available to the public and are of limited value since they cannot be used to accurately determine how much radon you were exposed to, nor can they be used to predict whether you will develop harmful health effects. |

## 1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the

Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), the Food and Drug Administration (FDA), and the U.S. Nuclear Regulatory Commission (USNRC).

Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR), the National Institute for Occupational Safety and Health (NIOSH), and the FDA.

Regulations and recommendations can be expressed as “not-to-exceed” levels, that is, levels of a toxic substance in air, water, soil, or food that do not exceed a critical value that is usually based on levels that affect animals; they are then adjusted to levels that will help protect humans. Sometimes these not-to-exceed levels differ among federal organizations because they used different exposure times (an 8-hour workday, a 24-hour day, or a work-year), different animal studies, or other factors.

Recommendations and regulations are also updated periodically as more information becomes available. For the most current information, check with the federal agency or organization that provides it.

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| **Air** | EPA recommends fixing your home if measured indoor levels of radon are 4 or more pCi per liter (pCi/L) of air EPA also notes that radon levels less than 4 pCi/L still pose a health risk and can be reduced in many cases. The EPA recommends using a certified radon mitigation specialist if indoor radon levels need to be reduced to ensure that appropriate methods are used to reduce radon levels.<br><br>The Mine Safety and Health Administration (MSHA) has adopted an exposure limit of 4 Working Level Months (WLM) per year for people who work in mines (WLMs basically combine the concentration of radon in mine air with length of exposure inside the mine).<br><br>The Nuclear Regulatory Commission published a table of allowable exposure to radon by workers and allowable releases of radon to the environment by its licensees. |

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| **Water** | In the 1990s, EPA introduced a proposal to limit levels of radon in drinking water. As of August 2008 the proposal had not been adopted as a regulation. |

## 1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department, or contact ATSDR at the address and phone number below.

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses that result from exposure to hazardous substances.

Toxicological profiles are also available on-line at www.atsdr.cdc.gov and on CD-ROM. You may request a copy of the ATSDR ToxProfiles™ CD-ROM by calling the toll-free information and technical assistance number at 1-800-CDCINFO (1-800-232-4636), by e-mail at cdcinfo@cdc.gov, or by writing to:

Agency for Toxic Substances and Disease Registry
Division of Toxicology and Environmental Medicine
1600 Clifton Road NE
Mailstop F-32
Atlanta, GA 30333
Fax: 1-770-488-4178

Organizations for-profit may request copies of final Toxicological Profiles from the following:

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
Phone: 1-800-553-6847 or 1-703-605-6000
Web site: http://www.ntis.gov/

# PUBLIC HEALTH STATEMENT
# SELENIUM
# CAS#: 7782-49-2

**Division of Toxicology** **September 2003**

This Public Health Statement is the summary chapter from the Toxicological Profile for Selenium. It is one in a series of Public Health Statements about hazardous substances and their health effects. A shorter version, the ToxFAQs™, is also available. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present. For more information, call the ATSDR Information Center at 1-888-422-8737.

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This public health statement tells you about selenium and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Selenium has been found in at least 508 of the 1,623 current or former NPL sites. However, the total number of NPL sites evaluated for selenium is not known. As more sites are evaluated, the sites at which selenium is found may increase. This information is important because exposure to selenium at high levels may harm you and because these sites may be sources of exposure. A minimum dietary level of selenium is required for good health.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact. If you are exposed to selenium, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it/them. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

## 1.1 WHAT IS SELENIUM?

Selenium is a naturally occurring, solid substance that is widely but unevenly distributed in the earth's crust. It is also commonly found in rocks and soil. Selenium, in its pure form of metallic gray to black crystals, is often referred to as elemental selenium or selenium dust. Elemental selenium is commercially produced, primarily as a by-product of copper refining. Selenium is not often found in the environment in its elemental form, but is usually combined with other substances. Much of the selenium in rocks is combined with sulfide minerals or with silver, copper, lead, and nickel minerals. Selenium also combines with oxygen to form several substances that are white or colorless crystals. Some selenium compounds are gases. Selenium and its compounds are used in some photographic devices, gun bluing (a liquid solution used to clean the metal parts of a gun), plastics, paints, anti-dandruff shampoos, vitamin and mineral supplements, fungicides, and certain types of glass. For example, selenium sulfide is used in anti-dandruff shampoos by the common trade name Selsun Blue. Selenium is also used to prepare drugs and as a nutritional feed supplement for poultry and livestock.

**1.2 WHAT HAPPENS TO SELENIUM WHEN IT ENTERS THE ENVIRONMENT?**

Selenium occurs naturally in the environment. As an element, selenium cannot be created or destroyed, although selenium can change forms in the environment. Weathering of rocks and soils may result in low levels of selenium in water, which may be taken up by plants. Weathering also releases selenium into the air on fine dust-like particles. Volcanic eruptions may release selenium in air. Selenium commonly enters the air from burning coal or oil. Selenium that may be present in fossil fuels combines with oxygen when burned, which may then react with water to form soluble selenium compounds. Airborne particles of selenium, such as in ash, can settle on soil or surface water. Disposal of selenium in commercial products and waste could also increase the amount of selenium in soil. The forms and fate of selenium in soil depend largely on the acidity of the surroundings and its interaction with oxygen. In the absence of oxygen when the soil is acidic, the amount of selenium that can enter plants and organisms should be low. Elemental selenium that cannot dissolve in water and other insoluble forms of selenium are less mobile and will usually remain in the soil, posing smaller risk of exposure. Selenium compounds that can dissolve in water are sometimes very mobile. Thus, there is an increased chance of exposure to these compounds. Selenium may enter surface water in irrigation drainage waters. Some evidence indicates that selenium can be taken up in tissues of aquatic organisms and possibly increase in concentration as the selenium is passed up through the food chain. Selenium concentrations in aquatic organisms have been a problem as a result of irrigation runoff in some dry areas of the United States.

**1.3 HOW MIGHT I BE EXPOSED TO SELENIUM?**

People are exposed to low levels of selenium daily through food, water, and air. Selenium is also an essential nutrient for humans and animals. However, selenium can be harmful when regularly taken in amounts higher than those needed for good health. People receive the majority of their daily intake of selenium from eating food, and to a lesser extent, from water intake. Estimates of the average intake of selenium from food for the U.S. population range from 71 to 152 millionths of a gram of selenium per person per day. Low levels of selenium can also be found in drinking water. Selenium levels are less than 10 parts of selenium in a billion parts of water (10 ppb) in 99.5% of drinking water sources tested. People may be exposed to higher-than-normal levels of selenium at hazardous waste sites by swallowing soil or water, or by breathing dust. In some parts of the United States, especially in the western states, some soils naturally have higher levels of selenium compounds. Some plants can build up selenium to levels that harm livestock feeding on them. In these areas, people could be exposed to too much selenium if they eat a lot of locally grown grains and vegetables or animal products that have built up high levels of selenium. People may also be exposed to selenium from industrial sources. Humans are normally not exposed to large amounts of selenium in the air, unless selenium dust or volatile selenium compounds are formed in their workplace. Occupations in which humans may be exposed to selenium in the air are the metal industries, selenium-recovery processes, paint manufacturing, and special trades.

**1.4 HOW CAN SELENIUM ENTER AND LEAVE MY BODY?**

Selenium from the environment mainly enters the body when people eat food containing selenium. The human body easily absorbs the organic selenium compounds (for example, selenoamino acids) when eaten, and makes them available where needed in the body. The selenium in drinking water is usually in the form of inorganic sodium selenate and sodium selenite; these forms of selenium are also easily absorbed from the digestive tract. The human body can change these inorganic selenium compounds into forms that it can use. Selenium in the air may also enter your body when you breathe it.

Hazardous waste sites at which selenium is present could represent a major source of exposure. The way that selenium can enter the body from a particular site depends on such factors as whether vegetables are grown in soil in which selenium from the site has been deposited, whether water at the site contains selenium and is able to flow into drinking water supplies, and whether selenium dust blows into the air. As mentioned earlier, specific conditions at a site can greatly influence which selenium compounds form and whether they can move in the environment to places where people might be exposed. Therefore, it is important to know that the presence of selenium at a site does not necessarily mean that people are being exposed to it. Specific tests of locally grown food, drinking water, and air must be done to find out whether exposure is occurring. You should also be aware that selenium compounds, including those used in some medicated dandruff shampoos, are not easily absorbed through the skin.

Most of the selenium that enters the body quickly leaves the body, usually within 24 hours. Beyond what the body needs, selenium leaves mainly in the urine, but also in feces and breath. Selenium in the urine increases as the amount of the exposure goes up. Selenium can build up in the human body, however, if exposure levels are very high or if exposure occurs over a long time. The amount that builds up in the body depends on the chemical form of the selenium. It builds up mostly in the liver and kidneys but also in the blood, lungs, heart, and testes. Selenium can build up in the nails and in hair, depending on time and amount of exposure.

**1.5 HOW CAN SELENIUM AFFECT MY HEALTH?**

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

The general public rarely breathes high levels of selenium, although some people may be exposed to selenium dust and selenium compounds in workplace air. Dizziness, fatigue, and irritation of mucous membranes have been reported in people exposed to selenium in workplace air at concentrations higher than legal levels. In extreme cases, collection of fluid in the lungs (pulmonary edema) and severe bronchitis have been reported. The exact exposure levels at which these effects might occur are not known, but they become more likely with increasing amounts of selenium and with increasing frequency of exposure.

The normal intake of selenium by eating food is enough to meet the Recommended Daily Allowance (RDA) for this essential nutrient. However, as discussed in Chapters 2 and 3 of this profile, selenium compounds can be harmful at daily dietary levels that are higher than needed. The seriousness of the effects of excess selenium depends on how much selenium is eaten and how often. Intentional or accidental swallowing of a large amount of sodium selenate or sodium selenite (for example, a very large quantity of selenium supplement pills) could be life-threatening without immediate medical treatment. Even if mildly excessive amounts of selenium are eaten over long periods, brittle hair and deformed nails can develop. In extreme cases, people may lose feeling and control in arms and legs. These health effects, called selenosis, were seen in several villages in China where people were exposed to foods high in selenium for months to years. No human populations in the United States have been reported with long-term selenium poisoning, including populations in the western part of the country where selenium levels are naturally high in the soil. Because most people in the United States eat foods produced in many different areas, overexposure to selenium in food is unlikely to occur.

In some regions of China where soil levels of selenium are very low, not eating enough selenium has resulted in health effects. Selenium is used by the body in antioxidant enzymes that protect against damage to tissues done by oxygen, and in an enzyme that affects growth and metabolism. Not eating enough selenium can cause heart problems and muscle pain. Muscle pain has also been noted in people fed intravenously for a long time with solutions that did not contain selenium. Babies born early may be more sensitive to not having enough selenium, and this may contribute to lung effects. In the United States, selenium in food is sufficient to meet the RDA and prevent harmful effects from not enough selenium.

Upon contact with human skin, industrial selenium compounds have been reported to cause rashes, redness, heat, swelling, and pain. Brief, acute exposure of the eyes to selenium dioxide as a dust or fume in workplace air may result in burning, irritation, and tearing. However, only people who work in industries that process or use selenium or selenium compounds are likely to come into contact with levels high enough to cause eye irritation.

Studies of laboratory animals and people show that most selenium compounds probably do not cause cancer. In fact, some studies of cancer in humans suggest that lower-than-normal selenium levels in the diet might increase the risk of cancer. Other studies suggest that dietary levels of selenium that are higher than normal might reduce the risk of cancer in humans. However, taking selenium so that your daily amount is greater than that required might just increase your risk of selenium poisoning.

Based on studies done until 1987, the International Agency for Research on Cancer (IARC) determined that selenium and selenium compounds could not be classified as to their ability to cause cancer in humans. However, since then, the EPA has determined that one specific form of selenium, called selenium sulfide, is a probable human carcinogen. Selenium sulfide is the only selenium compound shown to cause cancer in animals. Rats and mice that were fed selenium sulfide daily at very high levels developed cancer. Selenium sulfide is not present in foods, and it is a very different chemical from the organic and inorganic selenium compounds found in foods and in the environment. Also, if introduced into the environment, selenium sulfide does not dissolve readily in water and would probably bind tightly to the soil, further reducing any chance of exposure. Because selenium sulfide is not absorbed through the skin, the use of anti-dandruff shampoos containing selenium sulfide is generally considered safe.

Very high amounts of selenium have caused decreased sperm counts, increased abnormal sperm, changes in the female reproductive cycle in rats, and changes in the menstrual cycle in monkeys. The relevance of the reproductive effects of selenium exposure in animals studied to potential reproductive effects in humans is not known. Selenium compounds have not been shown to cause birth defects in humans or in other mammals.

**1.6 HOW CAN SELENIUM AFFECT CHILDREN?**

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans.

Children living near selenium waste sites or coal burning plants are likely to be exposed to higher environmental levels of selenium through breathing, touching soil, and eating contaminated soil. Children living in areas of China with high selenium in the soil had higher levels of selenium in the blood than adults from that area. Very few studies have looked at how selenium can affect the health of children. Children need small amounts of selenium for normal growth and development. Children will probably show the same sort of health effects from selenium exposure as adults, but some studies suggest that they may be less susceptible to health effects of selenium than adults.

We do not know if exposure to selenium could result in birth defects in people. Selenium compounds have not been shown to cause birth defects in humans or in other mammals. We have no information to suggest that there are any differences between children and adults in where selenium is found in the body or in how fast it enters or leaves the body. Studies in laboratory animals have shown that selenium crosses the placenta and enters the fetus. Studies in humans show that infants are supplied with selenium through breast milk, and therefore, women who were exposed to selenium by living near a waste site might transfer selenium to their babies. However, babies in areas of China with high selenium in the soil did not show any signs of health effects due to selenium, even though some of their parents did.

**1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO SELENIUM?**

If your doctor finds that you have been exposed to significant amounts of selenium, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

Since selenium occurs naturally in the environment, we cannot avoid exposure to it. Certain dietary supplements and anti-dandruff shampoos contain selenium in high levels. You should not exceed the recommended dosages when using these products.

Children living near selenium waste sites or coal burning plants are likely to be exposed to higher environmental levels of selenium through breathing, touching soil, and eating contaminated soil. Some children eat a lot of dirt. You should discourage your children from eating dirt. Make sure they wash their hands frequently and before eating. Discourage your children from putting their hands in their mouths or from other hand-to-mouth activity.

The primary route of human exposure to selenium is through eating food. People who irrigate their home gardens with groundwater containing high levels of selenium may grow and eat plants that contain high levels of selenium because this element is taken up in some plants. Fishermen and hunters of waterfowl who regularly eat fish and game from waterways with high selenium content may also consume above average levels of selenium. To reduce your family's exposure to selenium, obey any wildlife advisories issued by your state. Information on fish and wildlife advisories in your state is available from your state public health or natural resources department.

**1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO SELENIUM?**

Selenium can be measured in the blood, urine, and fingernails or toenails of exposed individuals. However, since selenium is an essential nutrient normally present in foods, low levels of selenium are normally found in body tissues and urine. Tests for selenium are most useful for people who have recently been exposed to high levels. Samples of blood, urine, or nails can be properly collected in a physician's office and sent to a laboratory that has the special equipment needed to measure selenium. Urine can be used to determine short-term exposure. Because red blood cells last about 120 days before they are replaced by newly made red blood cells, the presence of selenium in red blood cells can show whether a person was exposed to selenium during the 120 days before testing, but not if exposed more than 120 days before testing. Toenail clippings can be used to determine longer-term exposure.

Many methods are available to measure selenium levels in human tissue and the environment. However, none of the methods that are routinely available can measure or detect each selenium compound in one test, and better tests that measure lower levels of different selenium compounds are needed. Also, these tests cannot determine the exact levels of selenium you may have been exposed to or predict whether health effects will occur, even though very high amounts of selenium in blood are clearly related to selenosis. Some human as well as animal studies suggest that when people are exposed over a long period to higher-than-normal amounts of selenium, their bodies adjust to the higher amounts.

The length of time that selenium stays in the body after exposure stops depends on the form of selenium to which the person was exposed. Thus, it is difficult to predict how useful a test will be if some time has gone by since exposure stopped.

## 1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8 hour workday or a 24 hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for selenium include the following:

The EPA Office of Drinking Water regulates the amount of selenium allowed in drinking water.

Public water supplies are not allowed to exceed 50 ppb total selenium.

The FDA regulations allow a level of 50 ppb of selenium in bottled water. OSHA is responsible for setting regulations on selenium levels allowable in the workplace. The exposure limit for selenium compounds in the air for an 8 hour period is 0.2 mg selenium/$m^3$.

## 1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop F-32
Atlanta, GA 30333

**Information line and technical assistance:**

Phone: 888-422-8737
FAX: (770)-488-4178

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

**To order toxicological profiles, contact:**

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 800-553-6847 or 703-605-6000

**Reference**

Agency for Toxic Substances and Disease Registry (ATSDR). 2003. Toxicological profile for selenium. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

# PUBLIC HEALTH STATEMENT
# THORIUM
# CAS#: 7440-29-1

**Division of Toxicology** **October 1990**

This Public Health Statement is the summary chapter from the Toxicological Profile for Thorium. It is one in a series of Public Health Statements about hazardous substances and their health effects. A shorter version, the ToxFAQs™, is also available. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present. For more information, call the ATSDR Information Center at 1-888-422-8737.

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This Statement was prepared to give you information about thorium and to emphasize the human health effects that may result from exposure.

At this time, thorium has been found above background levels at 16 out of 1177 National Priorities List (NPL) hazardous waste sites. We do not know how many of the 1,177 NPL sites have been evaluated for thorium. As EPA evaluates more sites, the number of sites at which thorium is found at above background levels may change. Because these sites are potential or actual sources of human exposure to thorium and because thorium may cause harmful health effects, this information is important for you to know.

When a radioactive chemical is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment as a radioactive chemical emission. This emission, which is also called a release, does not always lead to exposure. You are exposed only when you come into contact with the radioactive chemical. You can come into contact with it in the environment through breathing air, eating, drinking or smoking substances containing the radioactive chemical. Exposure may also result from skin contact with the radioactive chemical alone, or with a substance containing it. Exposure can also occur by being near radioactive chemicals at concentrations that may be found at hazardous waste sites or industrial accidents.

If you are exposed to a hazardous chemical, several factors determine whether harmful effects will occur and the type and severity of those health effects. These factors include the dose (how much), the duration (how long), the pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, sex, eating habits, family traits, life style, and state of health.

## 1.1 WHAT IS THORIUM?

Thorium is a naturally-occurring, radioactive metal. Small amounts of thorium are present in all rocks, soil, above-ground and underground water, plants, and animals. These small amounts of thorium contribute to the weak background radiation for such substances. Soil commonly contains an average of about 6 parts of thorium per million parts (ppm) of soil. Rocks in some underground mines may also contain thorium in a more concentrated form. After these rocks are mined, thorium is usually concentrated and changed into thorium dioxide or other chemical forms. Thorium-bearing rock that has had most of the thorium removed from it is called "depleted" ore or tailings.

More than 99% of natural thorium exists in the form (isotope) thorium-232. Besides this natural thorium isotope, there are more than 10 other different isotopes that can be artificially produced. In the environment, thorium-232 exists in various combinations with other minerals, such as silica. Most thorium compounds commonly found in the environment do not dissolve easily in water and do not evaporate from soil or water into the air.

The thorium isotope-232 is not stable. It breaks down into two parts. This process of breaking down is called decay. The decay of thorium-232 produces a small part called "alpha" radiation and a large part called the decay product. The decay product of thorium-232 also is not stable. Like thorium-232, it in turn breaks down to an unstable isotope and the process continues until a stable product is formed. During these decay processes, the parent thorium-232, its decay products, and their next decay products produce a series of new substances (including radium and radon), alpha and beta particles, and gamma radiation. The alpha particles can travel only very short distances through most materials and cannot go through human skin. The gamma radiation can travel farther and can easily go through human skin. The decay of thorium-232 into its decay products happens very slowly. In fact, it takes about 14 billion years for half the thorium-232 to change into new forms. Fourteen billion years is called the radioactive half-life of thorium-232.

Due to the extremely slow rate of decay, the total amount of natural thorium in the earth remains almost the same, but it can be moved from place to place by nature and people. For example, when rocks are broken up by wind and water, thorium or its compounds becomes a part of the soil. When it rains, the thorium-containing soil can be washed into rivers and lakes. Also, activities such as burning coal that contains small amounts of thorium, mining or milling thorium, or making products that contain thorium also release thorium into the environment. Smaller amounts of other isotopes of thorium are produced usually as decay products of uranium-238, uranium-235, and thorium-232, and as unwanted products of nuclear reactions.

Thorium is used to make ceramics, lantern mantles, and metals used in the aerospace industry and in nuclear reactions. Thorium can also be used as a fuel for generating nuclear energy. More than 30 years ago thorium oxides were used in hospitals to make certain kinds of diagnostic X-ray photographs.

### 1.2 HOW MIGHT I BE EXPOSED TO THORIUM?

Since thorium is found almost everywhere, you will be exposed to small amounts of it in the air you breathe and in the food and water you eat and drink. Scientists know, roughly, the average amounts of thorium in food and drinking water. Most people in the United States eat some thorium with their food every day. Normally, very little of the thorium in lakes, rivers, and oceans gets into the fish or seafood we eat. The amounts in the air are usually so small that they can be ignored.

There may be more thorium than normal near an uncontrolled hazardous waste site in which thorium has not been disposed of properly. Consequently, you may be exposed to slightly more thorium if you live near one of these sites because you could breathe windblown dust containing thorium or eat food grown in soil contaminated with thorium. Children playing near a waste site could get thorium into their bodies if they eat contaminated soil. You could also be exposed to more thorium than normal if you work in an industry that mines, mills, or manufactures products containing thorium, or work in a research laboratory performing experiments with thorium. Larger-than-normal amounts of thorium might also enter the environment through accidental releases from thorium processing plants.

## 1.3 HOW CAN THORIUM ENTER AND LEAVE MY BODY?

Only a small amount of the thorium that you breathe or swallow in food, water, or soil enters your blood. One animal study has shown that thorium can enter the body if it is placed on the skin. After breathing thorium, you will usually sneeze, cough, or breathe out some of it within minutes. Some forms of thorium can stay in your lungs for long periods of time. However, in most cases, the small amount of thorium left in your lungs will leave your body in the feces and urine within days. After you eat or drink thorium, almost all of it leaves your body in the feces. The small amount of thorium left in your body may enter your bones from the blood and stay there for many years. The main way thorium will enter your body is by breathing dust contaminated with thorium.

## 1.4 HOW CAN THORIUM AFFECT MY HEALTH?

Studies of thorium workers have shown that breathing thorium dust may cause an increased chance of developing lung disease and cancer of the lung or pancreas many years after being exposed. Changes in the genetic material of body cells have also been shown to occur in workers who breathed thorium dust. Liver diseases and effects on the blood have been found in people injected with thorium in order to take special X-rays.

Many types of cancer have also been shown to occur in these people many years after thorium was injected into their bodies. Since thorium is radioactive and may be stored in bone for a long time, bone cancer is also a potential concern for people exposed to thorium.

Animal studies have shown that breathing in thorium may result in lung damage. Other studies in animals suggest drinking massive amounts of thorium can cause death from metal poisoning. The presence of large amounts of thorium in your environment could result in exposure to more hazardous radioactive decay products of thorium, such as radium and thoron, which is an isotope of radon. Thorium is not known to cause birth defects or to affect the ability to have children.

## 1.5 WHAT LEVELS OF EXPOSURE HAVE RESULTED IN HARMFUL HEALTH EFFECTS?

Thorium is odorless and tasteless, so you cannot tell if you are being exposed to thorium. We know very little about specific exposure levels of thorium that result in harmful effects in people or animals. High levels of exposure have been shown to cause death in animals, but no direct cause of death could be determined and no other health effects have been reported.

### 1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO THORIUM?

Special tests that measure the level of radioactivity from thorium or thorium isotopes in your urine, feces, and air you breathe out can determine if you have been exposed to thorium. These tests are useful only if run within several days to a week after exposure. The tests cannot, however, tell you if your health will be affected by the exposure. The tests can be run only with special equipment and are probably not available at your local clinic or hospital.

### 1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The EPA has set a drinking water limit of 15 picocuries per liter (15 pCi/L) of water for gross alpha particle activity and 4 millirems per year for beta particles and photon activity (for example, gamma radiation and X-rays).

The federal recommendations have been updated as of July 1999.

### 1.8 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop F-32
Atlanta, GA 30333

**Information line and technical assistance:**

Phone: 888-422-8737
FAX: (770)-488-4178
ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

**To order toxicological profiles, contact:**

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 800-553-6847 or 703-605-6000

**Reference**

Agency for Toxic Substances and Disease Registry (ATSDR). 1990. Toxicological profile for thorium. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

# PUBLIC HEALTH STATEMENT
# URANIUM
# CAS#: 7440-61-1

**Division of Toxicology** **September 1999**

This Public Health Statement is the summary chapter from the Toxicological Profile for Uranium. It is one in a series of Public Health Statements about hazardous substances and their health effects. A shorter version, the ToxFAQs™, is also available. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present. For more information, call the ATSDR Information Center at 1-888-422-8737.

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This public health statement tells you about uranium and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sitesmake up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Elevated uranium levels have been found in at least 54 of the 1,517 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which uranium is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are normally exposed to a substance only when you come in contact with it. You may been exposed by breathing, eating, or drinking the substance or by skin contact. However, since uranium is radioactive, you can also be exposed to its radiation if you are near it.

If you are exposed to uranium, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

## 1.1 WHAT IS URANIUM?

Uranium is a natural and commonly occurring radioactive element. It is found in very small amounts in nature in the form of minerals, but may be processed into a silver-colored metal. Rocks, soil, surface and underground water, air, and plants and animals all contain varying amounts of uranium. Typical concentrations in most materials are a few parts per million (ppm). This corresponds to around 4 tons of uranium in 1 square mile of soil 1 foot deep, or about half a teaspoon of uranium in a typical 8-cubic yard dump truck load of soil. Some rocks and soils may also contain greater amounts of uranium. If the amount is great enough, the uranium may be present in commercial quantities and can be mined. After the uranium is extracted, it is converted into uranium dioxide or other chemical forms by a series of chemical processes known as milling. The residue remaining after the uranium has been extracted is called mill tailings. Mill tailings contain a small amount of uranium, as well as other naturally radioactive waste products such as radium and thorium.

# PUBLIC HEALTH STATEMENT
# URANIUM
# CAS#: 7440-61-1

**Division of Toxicology** **September 1999**

Natural uranium is a mixture of three types (or isotopes) of uranium, written as 234U, 235U, and 238U, or as U-234, U-235, and U-238, and read as uranium two thirty-four, etc. All three isotopes behave the same chemically, so any combination of the three would have the same chemical effect on your body. But they are different radioactive materials with different radioactive properties. That is why we must look at the actual percentages of the three isotopes in a sample of uranium to determine how radioactive the uranium is. For uranium that has been locked inside the earth for millions of years, we know the percentage of each isotope by weight and by radioactivity. By weight, natural uranium is about 0.01% 234U, 0.72% 235U, and 99.27% 238U. About 48.9% of the radioactivity is associated with 234U, 2.2% is associated with 235U, and 48.9% is associated with 238U.

The weight and radioactivity percentages are different because each isotope has a different physical half-life. Radioactive isotopes are constantly changing into different isotopes by giving off radiation. The half-life is the time it takes for half of that uranium isotope to give off its radiation and change into a different element. The half-lives of uranium isotopes are very long (244 thousand years for 234U, 710 million years for 235U, and 4½ billion years for 238U). The shorter half-life makes 234U the most radioactive, and the longer half-life makes 238U the least radioactive. If you have one gram of each isotope side by side, the 234U will be about 20 thousand times more radioactive and the 235U will be 6 times more radioactive than the 238U.

Uranium is measured in units of mass (grams) or radioactivity (curies or becquerels), depending on the type of equipment available or the level that needs to be measured. The becquerel (Bq) is a new internationalunit, and the curie (Ci) is a traditional unit; both are currently used. A Bq is the amount of radioactive material in which 1 atom transforms every second, and a Ci is the amount of radioactive material in which 37 billion atoms transform every second. The mass and activity ratios given in the previous paragraph are those found in rocks inside the earth's crust, where 1.5 gram of uranium is equivalent to 1 millionth of a Ci (µCi). Although this ratio can vary in air, soil, and water, the conversions made in this profile use the 1.5-to-1 ratio unless the actual isotope ratios are known. When both mass and radioactivity units are shown, the first is normally the one reported in the literature. Some of the values may be rounded to make the text easier to read.

The uranium isotopes in the earth were present when the earth was formed. Both 235U and 238U have such long half-lives that part of the uranium originally on earth is still here, waiting to give off its radiation. The original 234U would have decayed away by now, but new 234U is constantly being made from the decay of 238U. When 238U gives off its radiation, it changes or decays through a series of different radioactive materials, including 234U. This series, or decay chain, ends when a stable, non-radioactive substance is made. This element is lead.

For uranium that has been in contact with water, the natural weight and radioactivity percentages can vary slightly from the percentages mentioned in the previous paragraphs. We don't fully understand why that happens in nature, but measurements show us that it does. The processing of uranium for industrial and governmental use can also change the ratios. We give these ratios special names if they were changed by human activities. If the fraction of 235U is increased, we call it enriched uranium. However, if the portion of 235U is decreased, we call it depleted uranium. The differences between the weight and radioactivity ratios matter when we want to convert between radioactivity and mass, and when we talk about how toxic uranium might be. Depleted uranium is less radioactive than natural uranium, and enriched uranium is more radioactive than natural uranium.

The industrial process called enrichment is used to increase the amount of 234U and 235U and decrease the amount of 238U in natural uranium. The product of this process is enriched uranium, and the leftover is depleted uranium. Enriched uranium is more radioactive than natural uranium, and natural uranium is more radioactive than depleted uranium. When enriched uranium is 97.5% pure 235U, the same weight of enriched uranium has about 75 times the radioactivity as natural uranium. This is because enriched uranium also contains 234U, which is even more radioactive than 235U. The 235U is responsible for most of the radioactivity in enriched uranium. Natural uranium is typically about two times more radioactive than depleted uranium. Other isotopes of uranium called 232U and 233U are produced by industrial processes. These are also much more radioactive than natural uranium.

The total amount of natural uranium on earth stays almost the same because of the very long half-lives of the uranium isotopes. The natural uranium can be moved from place to place by nature or by people, and some uranium is removed from the earth by mining. When rocks are broken up by water or wind, uranium becomes a part of the soil. When it rains, the soil containing uranium can be carried into rivers and lakes. Wind can blow dust that contains uranium into the air.
Natural uranium is radioactive but poses little radioactive danger because it gives off very small amounts of radiation. Uranium transforms into another element and gives off radiation. In this way uranium transforms into thorium and gives off a particle called an alpha particle or alpha radiation. Uranium is called the parent, and thorium is called the transformation product. When the transformation productis radioactive, it keeps transforming until a stable product is formed. During these decay processes, the parent uranium, its decay products, and their subsequent decay products each release radiation. Radon and radium are two of these products. Unlike other kinds of radiation, the alpha radiation ordinarily given off by uranium cannot pass through solid objects, such as paper or human skin. For more information on radiation, see Appendix D and the glossary at the end of this profile or the ASTDR Toxicological Profile for Ionizing Radiation.

The main civilian use of uranium is in nuclear power plants and on helicopters and airplanes. It is also used by the armed forces as shielding to protect Army tanks, parts of bullets and missiles to help them go through enemy armored vehicles, as a source of power, and in nuclear weapons. Very small amounts are used to make some ceramic ornament glazes, light bulbs, photographic chemicals, and household products. Some fertilizers contain slightly higher amounts of natural uranium.

## 1.2 WHAT HAPPENS TO URANIUM WHEN IT ENTERS THE ENVIRONMENT?

Uranium is a naturally occurring radioactive material that is present to some degree in almost everything in our environment, including soil, rocks, water, and air. It is a reactive metal, so it is not found as free uranium in the environment. In addition to the uranium naturally found in minerals, the uranium metal and compounds that are left after humans mine and process the minerals can also be released back to the environment in mill tailings. This uranium can combine with other chemicals in the environment to form other uranium compounds. Each of these uranium compounds dissolves to its own special extent in water, ranging from not soluble to very soluble. This helps determine how easily the compound can move through the environment, as well as how toxic it might be.

The amount of uranium that has been measured in air in different parts of the United States by EPA ranges from 0.011 to 0.3 femtocuries (0.00002 to 0.00045 micrograms) per cubic meter ($m^3$). (One femtocurie is equal to 1 picocurie [pCi] divided by 1,000. A picocurie [pCi] is 1 one-trillionth of a curie and a microgram [µg] is one millionth of a gram. Even at the higher concentration, there is so little uranium in a cubic meter of air that less than one atom transforms each day.

In the air, uranium exists as dust. Very small dust-like particles of uranium in the air fall out of the air onto surface water, plant surfaces, and soil either by themselves or when rain falls. These particles of uranium eventually end up back in the soil or in the bottoms of lakes, rivers, and ponds, where they stay and mix with the natural uranium that is already there.

Uranium in water comes from different sources. Most of it comes from dissolving uranium out of rocks and soil that water runs over and through. Only a very small part is from the settling of uranium dust out of the air. Some of the uranium is simply suspended in water, like muddy water. The amount of uranium that has been measured in drinking water in different parts of the United States by EPA is generally less than 1.5 µg (1 pCi) for every liter of water. EPA has found that the levels of uranium in water in different parts of the United States are extremely low in most cases, and that water containing normal amounts of uranium is usually safe to drink. Because of the nature of uranium, not much of it gets into fish or vegetables, and most of that which gets into livestock is eliminated quickly in urine and feces.

Uranium is found naturally in soil in amounts that vary over a wide range, but the typical concentration is 3 µg (2 pCi) per gram of soil. Additional uranium can be added by industrial activities. Soluble uranium compounds can combine with other substances in the environment to form other uranium compounds. Uranium compounds may stay in the soil for thousands of years without moving downward into groundwater. When large amounts of natural uranium are found in soil, it is usually soil with phosphate deposits. The amount of uranium that has been measured in the phosphate-rich soils of north and central Florida ranges from 4.5 to 83.4 pCi of uranium in every gram of soil. In areas like New Mexico, where uranium is mined and processed, the amount of uranium per gram of soil ranges between 0.07 and 3.4 pCi (0.1–5.1 micrograms [µg]) of uranium per gram soil). The amount of uranium in soil near a uranium fuel fabrication facility in the state of Washington ranges from 0.51 to 3.1 pCi/gram (0.8–4.6 µg uranium/gram soil), with an average value of 1.2 pCi/gram (1.7 µg uranium/gram soil). These levels must be carefully compared with the levels in uncontaminated soil in that area, since they are within the normal ranges for uncontaminated soil.

Plants can absorb uranium from the soil onto their roots without absorbing it into the body of the plant. Therefore, root vegetables like potatoes and radishes that are grown in uranium- contaminated soil may contain more uranium than if the soil contained levels of uranium that were natural for the area. Washing the vegetable or removing its skin often removes most or all of the uranium.

### 1.3 HOW MIGHT I BE EXPOSED TO URANIUM?

Since uranium is found everywhere in small amounts, you always take it into your body from the air, water, food, and soil. Food and water have small amounts of natural uranium in them. People eat about 1–2 micrograms (0.6–1.0 picocuries) of natural uranium every day with their food and take in about 1.5 micrograms (0.8 picocuries) of natural uranium for every liter of water they drink, but they breathe in much lower amounts. Root vegetables, such as beets and potatoes, tend to have a bit more uranium than other foods. In a few places, there tends to be more natural uranium in the water than in the food. People in these areas naturally take in more uranium from their drinking water than from their foods. It is possible that you may eat and drink more uranium if you live in an area with naturally higher amounts of uranium in the soil or water or if you live near a uranium-contaminated hazardous waste site. You can also take in (or ingest) more uranium if you eat food grown in contaminated soil, or drink water that has unusually high levels of uranium. Normally, very little of the uranium in lakes, rivers, or oceans gets into the fish or seafood we eat. The amounts in the air are usually so small that they can be safely ignored. People who are artists, art or craft teachers, ceramic hobbyists, or glass workers who still use certain banned uranium-containing glazes or enamels may also be near to higher levels of uranium, but they will not necessarily take any into their bodies. People who work at factories that process uranium, work with phosphate fertilizers, or live near uranium mines have a chance of taking in more uranium than most other people. People who work on gyroscopes, helicopter rotor counterbalances, or control surfaces of airplanes may work with painted uranium metal, but the coating normally will keep them from taking in any uranium. People who work with armor-piercing weapons that contain uranium will be exposed to low levels of radiation while close to these weapons, but are not likely to take in any uranium. Those who fire uranium weapons, work with weapons with damaged uranium, or on equipment which has been bombarded with these weapons can be exposed to uranium and may wear protective clothes and masks to limit their intake. Larger-than-normal amounts of uranium might also enter the environment from erosion of tailings from mines and mills for uranium and other metals. Accidental discharges from uranium processing plants are possible, but these compounds spread out quickly into the air.

## 1.4 HOW CAN URANIUM ENTER AND LEAVE MY BODY?

We take uranium into our bodies in the food we eat, water we drink, and air we breathe. What we take in from industrial activities is in addition to what we take in from natural sources.

When you breathe uranium dust, some of it is exhaled and some stays in your lungs. The size of the uranium dust particles and how easily they dissolve determines where in the body the uranium goes and how it leaves your body. Uranium dust may consist of small, fine particles and coarse, big particles. The big particles are caught in the nose, sinuses, and upper part of your lungs where they are blown out or pushed to the throat and swallowed. The small particles are inhaled down to the lower part of your lungs. If they do not dissolve easily, they stay there for years and cause most of the radiation dose to the lungs from uranium. They may gradually dissolve and go into your blood. If the particles do dissolve easily, they go into your blood more quickly. A small part of the uranium you swallow will also go into your blood. The blood carries uranium throughout your body. Most of it leaves in your urine in a few days, but a little stays in your kidneys and bones.

When you eat foods and drink liquids containing uranium, most of it leaves within a few days in your feces and never enters your blood. A small portion will get into your blood and will leave your body through your urine within a few days. The rest can stay in your bones, kidneys, or other soft tissues. A small amount goes to your bones and may stay there for years. Most people have a very small amounts of uranium, about 1/5,000th of the weight of an aspirin tablet, in their bodies, mainly in their bones.

Although uranium is weakly radioactive, most of the radiation it gives off cannot travel far from its source. If the uranium is outside your body, such as in soil, most of its radiation cannot penetrate your skin and enter your body. To be exposed to radiation from uranium, you have to eat, drink, or breathe it, or get it on your skin. If uranium transformation products are also present, you can be exposed to their radiation at a distance.

## 1.5 HOW CAN URANIUM AFFECT MY HEALTH?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists must determine what the harmful effects are, how to test for them, how much of the chemical is required to produce each of the harmful effects, how we recognize an overexposure, and how to treat it.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as kidney or liver damage, cancer, or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

Uranium is a chemical substance that is also radioactive. Scientists have never detected harmful radiation effects from low levels of natural uranium, although some may be possible. However, scientists have seen chemical effects. A few people have developed signs of kidney disease after intake of large amounts of uranium. Animals have also developed kidney disease after they have been treated with large amounts of uranium, so it is possible that intake of a large amount of uranium might damage your kidneys. There is also a chance of getting cancer from any radio active material like uranium. Natural and depleted uranium are only weakly radioactive and are not likely to cause you to get cancer from their radiation. No human cancer of any type has ever been seen as a result of exposure to natural or depleted uranium. Uranium can decay into other radionuclides, which can cause cancer if you are exposed to enough of them for a long enough period. Doctors that studied lung and other cancers in uranium miners did not think that uranium radiation caused these cancers. The miners smoked cigarettes and were exposed to other substances that we know cause cancer, and the observed lung cancers were attributed to large exposures to radon and its radioactive transformation products.

The chance of getting cancer is greater if you are exposed to enriched uranium, because it is more radioactive than natural uranium. Cancer may not become apparent until many years after a person is exposed to a radioactive material (from swallowing or breathing it). Just being near uranium is not dangerous to your health because uranium gives off very little of the penetrating gamma radiation. However, uraniumis normally accompanied by the other transformation products in its decay chain, so you would be exposed to their radiation as well.

The Committee on the Biological Effects of Ionizing Radiation (BEIR IV) reported that eating food or drinking water that has normal amounts of uranium will most likely not cause cancer or other health problems inmost people. The Committee used data from animal studies to estimate that a small number of people who steadily eat food or drink water that has larger-than-normal quantities of uranium in it could get a kind of bone cancer called a sarcoma. The Committee reported calculations showing that if people steadily eat food or drink water containing about 1 pCi of uranium every day of their lives, bone sarcomas would be expected to occur in about 1 to 2 of every million people after 70 years, based on the radiation dose alone. However, we do not know this for certain because people normally ingest nly slightly more than this amount each day, and people who have been exposed to larger amounts have not been found to get cancer.

We do not know if exposure to uranium causes reproductive effects in people. Very high doses of uranium have caused reproductive problems (reduced sperm counts) in some experiments with laboratory animals. Most studies show no effects.

## 1.6 HOW CAN URANIUM AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans. Potential effects on children resulting from exposures of the parents are also considered.

Like adults, children are exposed to small amounts of uranium in air, food, and drinking water. However, no cases have been reported where exposure to uranium is known to have caused health effects in children. It is possible that if children were exposed to very high amounts of uranium they might have damage to their kidneys like that seen in adults. We do not know whether children differ from adults in their susceptibility to health effects from uranium exposure.

It is not known if exposure to uranium has effects on the development of the human fetus. Very high doses of uranium in drinking water can affect the development of the fetus in laboratory animals. One study reported birth defects and another reported an increase in fetal deaths. However, we do not believe that uranium can cause these problems in pregnant women who take in normal amounts of uranium from food and water, or who breathe the air around a hazardous waste site that contains uranium.

Very young animals absorb more uranium into their blood than adults when they are fed uranium. We do not know if this happens in children.

Measurements of uranium have not been made in pregnant women, so we do not know if uranium can cross the placenta and enter the fetus. In an experiment with pregnant animals, only a very small amount (0.03%) of the injected uranium reached the fetus. Even less uranium is likely to reach the fetus in mothers exposed by inhaling, swallowing, or touching uranium. No measurements have been made of uranium in breast milk. Because of the chemical properties of uranium, it is unlikely that it would concentrate in breast milk.

## 1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO URANIUM?

If your doctor finds that you have been exposed to significant amounts of uranium, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

It is possible that higher-than-normal levels of uranium may be in the soil at a hazardous waste site. Some children eat a lot of dirt. You should prevent your children from eating dirt. Make sure they wash their hands frequently, and before eating. If you live near hazardous waste site, discourage your children from putting their hands in their mouths or from engaging in other hand-to-mouth activities.

## 1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO URANIUM?

Yes, there are medical tests that can determine whether you have been exposed by measuring the amount of uranium in your urine, blood, and hair. Urine analysis is the standard test. If you take into your body a larger-than-normal amount of uranium over a short period, the amount of uranium in your urine may be increased for a short time. Because most uranium leaves the body within a few days, normally the amount in the urine only shows whether you have been exposed to a larger-than-normal amount within the last week or so. If the intake is large or higher-than-normal levels are taken in over a long period, the urine levels may be high for a longer period of time. Many factors can affect the detection of uranium after e xposure. These factors include the type of uranium you were exposed to, the amount you took into your body, and the sensitivity of the detection method. Also, the amount in your urine does not always accurately show how much uranium you have been exposed to. If you think you have been exposed to elevated levels of uranium and want to have your urine tested, you should do so promptly while the levels may still be high. In addition to uranium, the urine could be tested for evidence of kidney damage, by looking for protein, glucose, and nonprotein nitrogen, which are some of the chemicals that can appear in your urine because of kidney damage. Testing for these chemicals could determine whether you have kidney damage. However, since kidney damage is also caused by several common diseases, such as diabetes, it would not tell you if the damage was caused by the presence of uranium in your body.

A radioactivity counter can tell if your skin is contaminated with uranium, because uranium is radioactive. If you inhale large amounts of uranium, it may be possible to measure the amount of radioactivity in your body with special radiation measurement instruments.

## 1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

International and national organizations like the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) provide recommendations for protecting people from materials, like uranium, that give off ionizing radiation. The federal government considers these recommendations and develops regulations and guidelines to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the EPA, the Nuclear Regulatory Commission (NRC), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed as levels that are not to be exceeded in air, water, soil, or food that are usually based on levels that affect animals. Then they are adjusted with appropriate safety factors to help protect people. Sometimes these not-to-exceed evels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for uranium are discussed below.

EPA has not set a limit for uranium in air, but it has set a goal of no uranium in drinking water. EPA calls this the Maximum Contaminant Level Goal (MCLG), but recognizes that, currently, there is no practical way to meet this goal. Because of this, EPA proposed in 1991 to allow up to 20 µg of uranium per liter (20 µg/L) in drinking water, and states began regulating to achieve this level. EPA calls this the Maximum Contaminant Level (MCL). The MCL for uranium is based on calculations that if 150,000 people drink water that contains 20 µg/L of uranium for a lifetime, there is a chance that one of them may develop cancer from the uranium in the drinking water. In 1994, EPA considered changing the MCL to 80 µg per liter based on newer human intake and uptake values and the high cost of reducing uranium levels in drinking water supplies. In 1998, EPA temporarily dropped its 1991 limit, but is currently working to develop an appropriate limit based on a broader range of human and animal health studies. ATSDR, other federal agencies, Canada, and other professionals are advising EPA regarding a new MCL. Canada is currently developing its own national guideline value because that country has the richest known uranium ore deposits in the world and high uranium concentrations in some of its well water.

EPA has also decided that any accidental uranium waste containing 0.1 curies of radioactivity (150 kilograms) must be cleaned up. EPA calls this the Reportable Quantity Accidental Release. EPA also has established a standard for uranium mill tailings. In the workplace, NIOSH/OSHA has set a Recommended Exposure Limit (REL) and a Permissible Exposure Limit (PEL) of 0.05 mg/m$^3$ (34 pCi/m$^3$) for uranium dust, while the NRC has an occupational limit of 0.2 mg/m$^3$(130 pCi/m$^3$). The NRC has set uranium release limits at 0.06 pCi/m$^3$ (0.09 µg/m$^3$) of air and 300 pCi/liter (450 µg/liter) of water. NRC and OSHA expect that the public will normally be exposed to much lower concentrations.

## 1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop F-32
Atlanta, GA 30333

**Information line and technical assistance:**

Phone: 888-422-8737
FAX: (770)-488-4178

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

**To order toxicological profiles, contact:**

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 800-553-6847 or 703-605-6000

**Reference**

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological profile for uranium. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

# PUBLIC HEALTH STATEMENT
# Vanadium

**Division of Toxicology and Environmental Medicine** **September 2009**

This Public Health Statement is the summary chapter from the Toxicological Profile for Vanadium. It is one in a series of Public Health Statements about hazardous substances and their health effects. A shorter version, the ToxFAQs™, is also available. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present. For more information, call the ATSDR Information Center at 1-800-232-4636.

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This public health statement tells you about vanadium and the effects of exposure to it.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites are then placed on the National Priorities List (NPL) and are targeted for long-term federal clean-up activities. Vanadium has been found in at least 319 of the 1,699 current or former NPL sites. Although the total number of NPL sites evaluated for this substance is not known, the possibility exists that the number of sites at which vanadium is found may increase in the future as more sites are evaluated. This information is important because these sites may be sources of exposure and exposure to this substance may be harmful.

When a substance is released either from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. Such a release does not always lead to exposure. You can be exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact.

If you are exposed to vanadium, many factors will determine whether you will be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider any other chemicals you are exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

# PUBLIC HEALTH STATEMENT
# Vanadium

**Division of Toxicology and Environmental Medicine** **September 2009**

## 1.1 WHAT IS VANADIUM?

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| **Description** | Vanadium is a naturally occurring element. It is widely distributed in the earth's crust at an average concentration of approximately 100 mg/kg. Vanadium is found in about 65 different minerals.<br><br>Depending on its form, vanadium can be a gray-white metal or light gray or white lustrous powder. Pure vanadium is a bright white, soft, and ductile metal. |
| **Uses**<br>• **Vanadium metal** | Vanadium is used in producing rust-resistant, spring, and high-speed tool steels. It is an important carbide stabilizer in making steels. |
| • **Vanadium pentoxide** | Vanadium pentoxide is used in ceramics and as a catalyst as well as in the production of superconductive magnets. |
| • **Vanadyl sulfate and sodium metavanadate** | Vanadyl sulfate and sodium metavanadate have been used in dietary supplements. |

## 1.2 WHAT HAPPENS TO VANADIUM WHEN IT ENTERS THE ENVIRONMENT?

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| **Sources** | Vanadium occurs naturally in soil, water, and air. Natural sources of atmospheric vanadium include continental dust, marine aerosol, and volcanic emissions.<br><br>Releases of vanadium to the environment are mainly associated with industrial sources, especially oil refineries and power plants using vanadium rich fuel oil and coal. Global human-made atmospheric releases of vanadium has been estimated to be greater than vanadium releases due to natural sources. Natural releases to water and soil are far greater overall than human-made releases to the atmosphere. |

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| **Break down** | Vanadium cannot be destroyed in the environment. It can only change its form or become attached or separated from airborne particulate, soil, particulate in water, and sediment. |
| **• Air** | Vanadium particles in the air settle to the ground or are washed out of the air by rain. Smaller particles, such as those emitted from oil-fueled power plants, may stay in the air for longer times and are more likely to be transported farther away from the site of release. |
| **• Water and soil** | The transport and partitioning of vanadium in water and soil is influenced by many factors including acidity of the water or soil and the presence of particulates. Vanadium can either be dissolved in water as dissolved ions or may become adsorbed to particulate matter. |

## 1.3 HOW MIGHT I BE EXPOSED TO VANADIUM?

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| **Food–primary source of exposure** | Most foods have naturally occurring low concentrations of vanadium. Seafood generally contains higher concentrations of vanadium than meat from land animals.<br><br>Daily intakes of vanadium from food ranging from 0.01 to 0.02 mg have been reported. Average vanadium concentrations in tap water are approximately 0.001 mg/L. Assuming that you drink approximately 2 L of water a day, a daily intake of approximately 0.002 mg of vanadium from tap water can be estimated for adults.<br><br>Vanadium also may be found in various commercial nutritional supplements and multivitamins in amounts ranging from 0.0004 to 12.5 mg, depending on the serving size recommended by the manufacturer. Consumption of some vanadium-containing supplements may result in intakes of vanadium that would exceed intakes from food and water.<br><br>Populations in areas with high levels of residual fuel oil consumption may also be exposed to above-background levels of vanadium, both from increased particulate deposition upon food crops and soil in the vicinity of power plants. |
| **Air** | Most people take in very little vanadium from breathing. The general population may also be exposed to airborne vanadium through inhalation, particularly in areas where use of residual fuel oils for energy production is high.<br><br>Individuals exposed to cigarette smoke may also be exposed to higher than background levels of vanadium. Approximately 0.0004 mg of vanadium is given off by in the smoke of one cigarette. |

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| **Water and soil** | Vanadium concentrations in surface water can range from approximately 0.04 to 220 µg/L depending on geographical location. |

## 1.4 HOW CAN VANADIUM ENTER AND LEAVE MY BODY?

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| **Enter your body**<br>• **Inhalation** | Some of the vanadium you breathe will enter your body through your lungs; however, we do not know how much will enter. |
| • **Ingestion** | A small amount of vanadium in food and water (3–20%) will enter your body through the digestive tract. The vanadium compounds you are exposed to will determine how much is absorbed. |
| • **Dermal contact** | We do not know how much vanadium will enter your body through your skin. It is likely that very little will pass through the skin. |

## 1.5 HOW CAN VANADIUM AFFECT MY HEALTH?

This section looks at studies concerning potential health effects in animal and human studies.

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| **Workers**<br>• **Inhalation** | Breathing air with vanadium pentoxide can result in coughing which can last a number of days after exposure. |
| **Laboratory animals**<br>• **Inhalation** | Damage to the lungs, throat, and nose have been observed in rats and mice exposed to vanadium pentoxide. |

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| **Humans**<br>• **Oral** | Nausea, mild diarrhea, and stomach cramps have been reported in people taking sodium metavanadate or vanadyl sulfate for the experimental treatment of diabetes.<br><br>Stomach cramps were also reported in a study of people taking about 13 mg vanadium/day. |
| **Laboratory animals**<br>• **Oral** | A number of effects have been found in rats and mice ingesting several vanadium compounds. The effects include:<br>• Decreases in number of red blood cells<br>• Increased blood pressure<br>• Mild neurological effects |
| **Cancer** | Lung cancer has been found in mice exposed to vanadium pentoxide.<br><br>The International Agency for Research on Cancer (IARC) has determined that vanadium is possibly carcinogenic to humans. |

## 1.6 HOW CAN VANADIUM AFFECT CHILDREN?

This section discusses potential health effects in humans from exposures during the period from conception to maturity at 18 years of age.

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| **Effects in children** | The health effects seen in children from exposure to toxic levels of vanadium are expected to be similar to the effects seen in adults. We do not know if children will be more sensitive to vanadium toxicity than adults. |

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| **Birth defects** | We do not know whether vanadium can cause birth defects in people.<br><br>Studies in animals exposed during pregnancy have shown that vanadium can cause decreases in growth and increases in the occurrence of birth defects. These effects are usually observed at levels which cause effects in the mother. |

## 1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO VANADIUM?

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| **Food** | Vanadium is a naturally occurring element that is widely distributed in the environment. It is found in many foods, typically in small amounts. You cannot avoid exposure to vanadium.<br><br>Exposure to the levels of vanadium that are naturally present in food and water are not considered to be harmful. |
| **Consumer products** | Consumption of some vanadium-containing supplements may result in intakes of vanadium that would exceed intakes from food and water. You should check with your physician before taking supplements containing vanadium to determine if such supplements are appropriate for you.<br><br>As a precaution, such products should have child-proof caps or should be kept out of reach of children so that children will not accidentally ingest them. |
| **Air** | Individuals exposed to cigarette smoke may also be exposed to higher-than-background levels of vanadium. Avoiding exposure to cigarette smoke may reduce exposure of you and your family to vanadium. |

## 1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO VANADIUM?

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| **Detecting exposure** | All people have small amounts of vanadium in their bodies. It can be measured in many tissues and fluids including blood, urine, and hair. |
| **Measuring exposure** | Measurements of vanadium concentrations in blood and urine can tell you whether you have been exposed to larger-than-normal amounts of vanadium. Blood and urinary vanadium levels are considered the most reliable indicators of occupational exposure to vanadium.<br><br>Measuring the concentration of vanadium in breathing air, drinking water, and food can help in determining how much vananium you are exposed to.<br><br>Measuring vanadium levels in hair is not a good indicator of occupational or environmental exposure to vanadium. |

## 1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. The EPA, the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA) are some federal agencies that develop regulations for toxic substances. Recommendations provide valuable guidelines to protect public health, but cannot be enforced by law. The Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH) are two federal organizations that develop recommendations for toxic substances.

Regulations and recommendations can be expressed as "not-to-exceed" levels. These are levels of a toxic substance in air, water, soil, or food that do not exceed a critical value. This critical value is usually based on levels that affect animals; they are then adjusted to levels that will help protect humans. Sometimes these not-to-exceed levels differ among federal organizations because they used different exposure times (an 8-hour workday or a 24-hour day), different animal studies, or other factors.

Recommendations and regulations are also updated periodically as more information becomes available. For the most current information, check with the federal agency or organization that provides it.

Some regulations and recommendations for vanadium include the following:

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| **Workplace air** | OSHA set a legal limit of 0.5 mg/m$^3$ for vanadium pentoxide respirable dust averaged over an 8-hour work day. A limit of 0.1 mg/m$^3$ for vanadium pentoxide fume has also been established. |

### 1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department, or contact ATSDR at the address and phone number below.

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses that result from exposure to hazardous substances.

Toxicological profiles are also available on-line at www.atsdr.cdc.gov and on CD-ROM. You may request a copy of the ATSDR ToxProfiles™ CD-ROM by calling the toll-free information and technical assistance number at 1-800-CDCINFO (1-800-232-4636), by e-mail at cdcinfo@cdc.gov, or by writing to:

Agency for Toxic Substances and Disease Registry
Division of Toxicology and Environmental Medicine
1600 Clifton Road NE
Mailstop F-62
Atlanta, GA 30333
Fax: 1-770-488-4178

Organizations for-profit may request copies of final Toxicological Profiles from the following:

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
Phone: 1-800-553-6847 or 1-703-605-6000
Web site: http://www.ntis.gov/